Investigation of mural painting materials discovered in the Ikh Bulag ruin of the Tuvshinshiree, Sukhbaatar Province, Mongolia

Investigation of mural painting materials discovered in the Ikh Bulag ruin of the Tuvshinshiree, Sukhbaatar Province, Mongolia

ANGARAGSUREN Odkhuu
(Kyoto University, Graduate School of Human and Environmental Studies)
KOHDZUMA Yohsei
(Nara National Research Institute of Cultural Properties)

Ⅰ. Introduction

Recently, some fragments of mural paintings have been found in ancient ruins in Mongolia. Unfortunately, the materials and pigments used in these discovered murals have not yet been investigated. In 2019, the Ikh Bulagiin Öndör Dovjoo ruin was excavated, which will be a valuable contribution to the medieval mural painting of Mongolia as part of the scope of the project, “History and archaeological research during the period of Old Turkic of Eastern Mongolia,” by the Institute of Archaeology of the Mongolian Academy of Sciences and Osaka University of Japan [Tsogtbaatar et al. 2019].

There are four historic ruins at the site known as Ikh Bulagiin Öndör Dovjoo located within the territory of IV District, Tuvshinshiree village, Sukhbaatar Province, Mongolia. The first excavation survey was in 2018, when ruins named “Dovjoon-1,” located on the western shore of the Togoot River, were excavated as part of the scope of the cooperative project and recorded in a field research report, “Archaeological Research of Dornod Mongol” between Mongolia and the United States [Amartuvshin et al. 2018]. The largest ruin was excavated in 2019 by the above research team [Tsogtbaatar et al. 2019].

This study’s aim was to investigate the materials and pigments used in the mural of the Ikh Bulagiin Öndör Dovjoo ruin in Mongolia.

1.1. Overview of the historical site

First, to confirm the structure, formation, dedication, absolute date, and to gather additional sources of ancient ruins from “Dovjoo” and “Svmiin Dovjoo,” researchers excavated ruins at “Öndör Dovjoo” located in Ikh Bulag. The ruin is located 510 km southeast of Ulaanbaatar; GPS coordinates (Figure 1_a). Although chronological analysis of the ruin has not been performed yet, the ruin was assumed to be between the 12th and 17th centuries [Tsogtbaatar et al. 2019]. Öndör Dovjoo had a platform of stone masonry in a hexagonal shape (Figure 1_b). The stone masonry used to form the hexagonal shape collapsed with the shape still noticeable. There were wall remnants with stone masonry to the rear of the platform’s center. They were 11.5 x 11.5m (Figure 1_b). Massive blue bricks and roofing pottery debris were found in the excavation, as were green- and red-pigmented wall painting fragments, and a few cases of fragments with gold leaf were discovered from southeast of the ruin’s center (Figure 1_c, d). Samples were taken from this area for this investigation. At the bottom of the north

Figure 1. (a) Map showing the excavation site

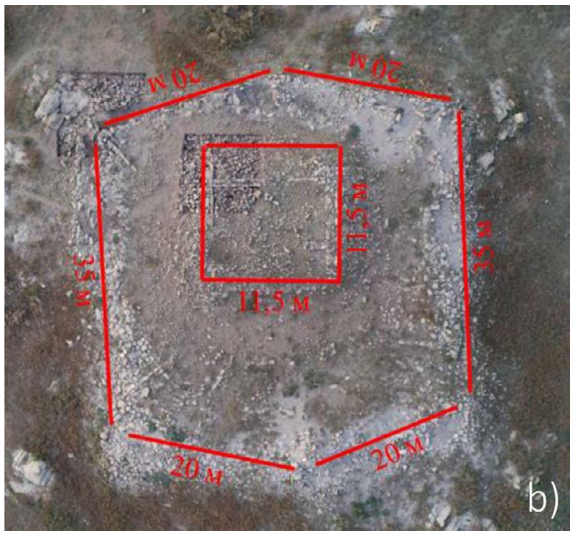


Figure 1. (b) The Ikh Bulgiin Öndör Dovjoo ruin

wall, something resembling white chalk was preserved [Tsogtbaatar et al. 2019]. A sample of this white material was also taken.

Ⅱ. Samples and analytical methods

2.1 Samples

The fragment samples from the ruin are shown below in Figures 2, 3, 4, and 5. To study the pigments and materials used in the mural painting fragments found at Ikh Bulagiin Öndör Dovjoo, both sides of the green and red-pigmented paints were examined along with the white material.

Three types of samples were chosen and identified as "No. 1," derived from the green pigment (Figure 2_a, b). Sample "No. 2" is the crushed white material (Figure 3). In addition, the red pigment was identified as "No. 3a" (Figure 4) and its opposite section was identified as "No. 3b" (Figure 5).

2.2. Features of the mural painting samples

The wall painting's structure was divided into a paint layer, plaster layer, and clay or mortar layer, which was the deepest. In some murals, mortar can be up to two layers thick, and without any plaster. The layer structure of Ikh Bulagiin Öndör Dovjoo's sample No. 1 is shown in Figure 6. The sample had a total thickness of approximately 12.95mm and consisted of paint, plaster, and mortar layers. B1, the paint layer, contains pigments of green, black, white, and red. Beneath the plaster layer,

Figure 1. (c) Location of mural fragments found within the ruin

Figure 1. (d) Fragments of mural painting

Figure 2. Sample No. 1 (a) front; (b) back

Figure 3. Sample No. 2

Figure 4. Sample No. 3a (Front side)

Figure 5. Sample No. 3b (Back side)

there was another layer of paint with red pigment (layer B_2).

The layer structure of sample No. 3 is shown in Figure 7. It has two paint layers on both sides. The total thickness of the sample is approximately 18.5mm. The P3 plaster layer in Figure 7, has a thickness of 2.05–2.9 mm and the mortar layer (M_2) has a thickness of approximately 2.8mm.

2.3. Analytical methods

Basic tools rented from the Center for Archaeological Operations of the Nara National Research Institute for Cultural Properties of Japan were used for the investigation. These devices were as follows: optical microscopy, X-ray fluorescence analysis (XRF) for revealing elements contained in minerals in material, X-ray diffractometry (XRD) for determining mineralogical crystals; scanning electron microscopy/ energy dispersive X-ray fluorescence analysis (SEM/ EDX) for recognizing pigment particle sizes, and X-ray radiography for testing inner structures.

2-2-1. Optical microscopy

The surface appearance and shape of the pigments were observed using stereo microscopes (Leica Z16 APOA, Leica MZ16, and OMRON Corporation VCR-FRM20LZ). The observation distance from the objective lens to the object was 30–150mm, with a magnification of 10–120X.

2-2-2. X-ray fluorescence analysis (XRF)

Elements of the mural plaster and pigments were measured using two separate XRF analyzers. For sample fragments of mural paintings, a desktop-type analyzer (Bruker EAGLE III) was used. For the mural paintings in situ, a handheld, nondestructive-type, NITON XL3t was similarly employed. The measurement conditions for the desktop analyzer were molybdenum target, tube voltage, current set to 40 kV and 30 μA, and a 100 s acquisition time. The conditions for the NITON XL3t were gold target, tube voltage 40 kV, tube current controlled automatically, and a 100 second acquisition time.

2-2-3. X-ray diffractometry

The mural plaster and pigments were identified by

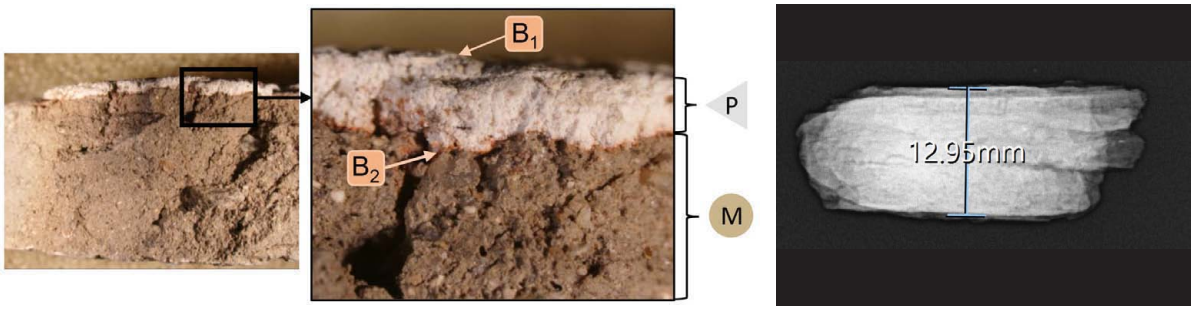


Figure 6. Layer structure of sample No. 1.

Right side monochrome photograph is an X-ray radiograph. Letter mark: paint layer (B_1, $_2$); plaster layer (P); mortar layer (M)

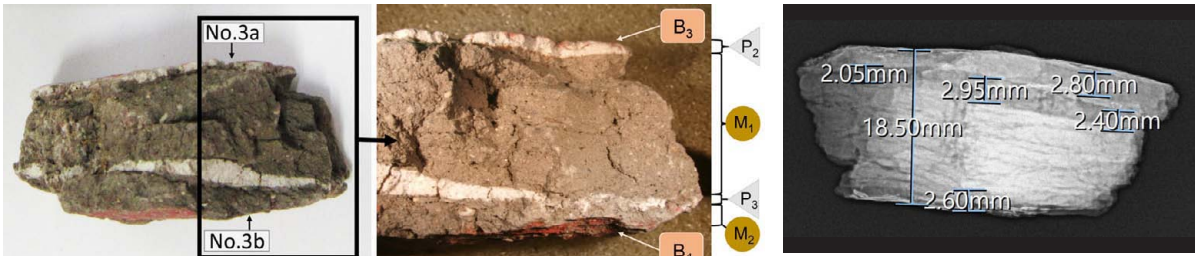


Figure 7. Layer structure of sample No. 3.

Right side monochrome photograph is an X-ray radiograph. Letter mark: paint layer (B_3, B_4), plaster layer (P_2 and P_3), mortar layer (M_1 and M_2)

XRD, Rigake Smartlab. The measurement conditions were as follows: Cu-K alpha radiation, tube voltage 40 kV, tube current 40 mA, and scan range (2θ/θ) 5–90°.

2-2-4. Scanning electron microscopy

The shape and elements of the pigment particles were observed and analyzed using SEM/EDX, JEOL JSM-IT100. The observation magnification was x30–x2000.

Ⅲ. Results and discussion

3.1.Sample No. 1

The green pigment in layer B_1 of sample No.1 excavated from Ikh Bulagiin Öndör Dovjoo, contained high amounts of the elements Cu and Cl in the XRF. The green pigment was identified as “atacamite” $Cu_7 2Cl_4(OH)10 \cdot H_2O$ by XRD.

Results of the XRD are shown in Figure 8. Atacamite is known to have been used as a pigment in Asia and the West [FitzHugh et al. 2003] In some additions, atacamite has been identified from green pigment in Mongolia and Inner Mongolia [Ryu 2018; Wei et al. 2010; Du et al. 2002].

It has been shown that pigments may be identified from the type of material particles. Crystalline structures

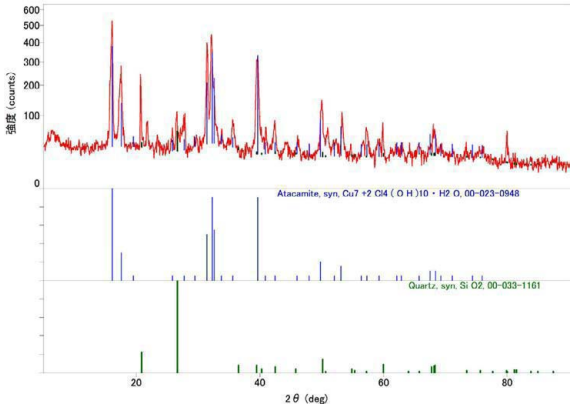


Figure 8. Results of the XRD analysis on green pigment from sample No. 1

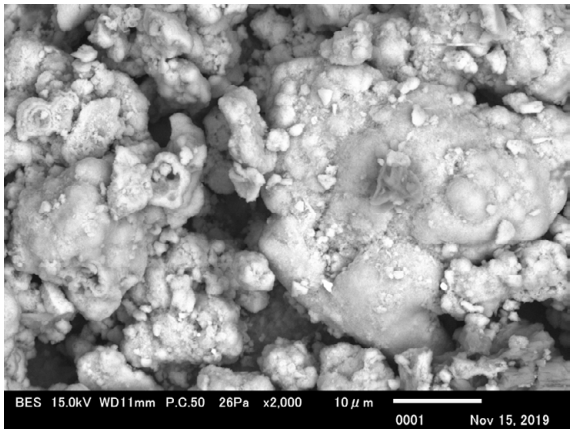


Figure 9. Scanning electron micrograph of green pigment from sample No. 1, magnification 2000x

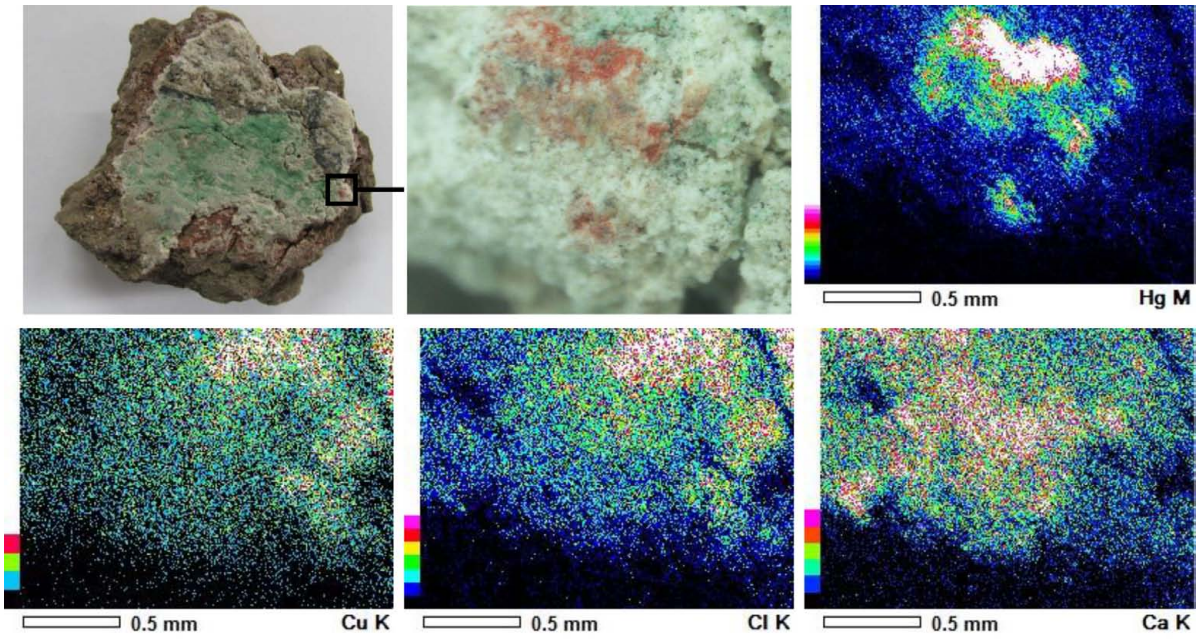


Figure 10. The results of SEM/EDX element mapping from sample No. 1, red pigment.
Measurement point: No. 1_05 of layer B_1

determine the shape of pigment particles. The green paint in layer B1 was observed at magnifications from 30-2000X on a scanning electron microscope (SEM), and the pigment particle was determined. The SEM image showed edgeless and smooth particles, common in paint with copper chloride hydroxide, “atacamite.” The particle shape and sizes were similar to the Övgön temple in Bulgan, Mongolia [Ryu 2020]. The particle size was approximately 1–5μм. Results of the SEM are in Figure 9.

Table 4 in Appendix 3 shows the results from XRF analysis of samples No. 1, No. 3a, and No. 3b. The elements Ca, Pb, As, Si, Fe, and Cu were detected from the white pigment at point No. 1_ 02 of layer B_1 of the fragment. The high level of Ca detected may be related to the material components of the plaster beneath the paint layer. In addition, because Pb was detected from point No. 1_02, white lead was estimated to be the pigment. Hg was revealed under both X-ray florescence analysis and SEM/EDX element mapping (Figure 10) of the red pigment at point No.1_05 of layer B_1. According to X-ray diffractometer analysis, it is definitive that cinnabar HgS red paint was used.

High Fe content was detected in the red pigment in layer B_2 at points No. 1_06 and No. 1_07. It is likely hematite Fe_2O_3. “Calcite,” $CaCO_3$ was detected from the plaster layer of sample No. 1. Measurement points for XRF and XRD are shown in Appendix 2: Figure 18, 19 and 20, as well as the results of these analyses are shown in Appendix 3: Table 4 and Table 5.

3.2. Sample No. 2

Orthoclase Al Si3O8 and quartz SiO_2 were detected from sample No. 2 using an X-ray diffractometer. The results of X-ray diffractometer analysis are shown in Figure 11.

3.3. Sample No. 3

After preparing the cross-sectional sample No.3, we examined the paint layer and the underlying structure. As a result of the optical microscopy, it was determined that section No.3a was a paint layer (B_3) on the top, and the second layer was a plaster layer (P_2). The third layer has been identified as a layer of red paint (B_5).

In addition, section No.3b consisted of three different layers: a paint layer, a mortar layer, and a plaster layer. The first layer was a paint layer (B_4) on section No.3b, the mortar layer (M_2) was under the B4 layer, and the third layer was a plaster layer (P_3). Figure 12 shows the cross-sectional image of sample No.3 and its layer structures.

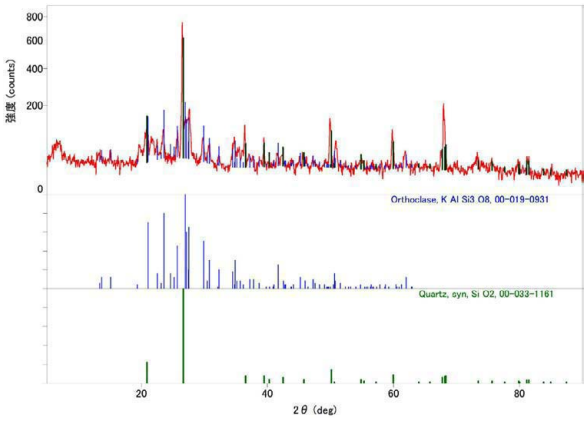


Figure 11. The results of XRD analysis on sample No. 2

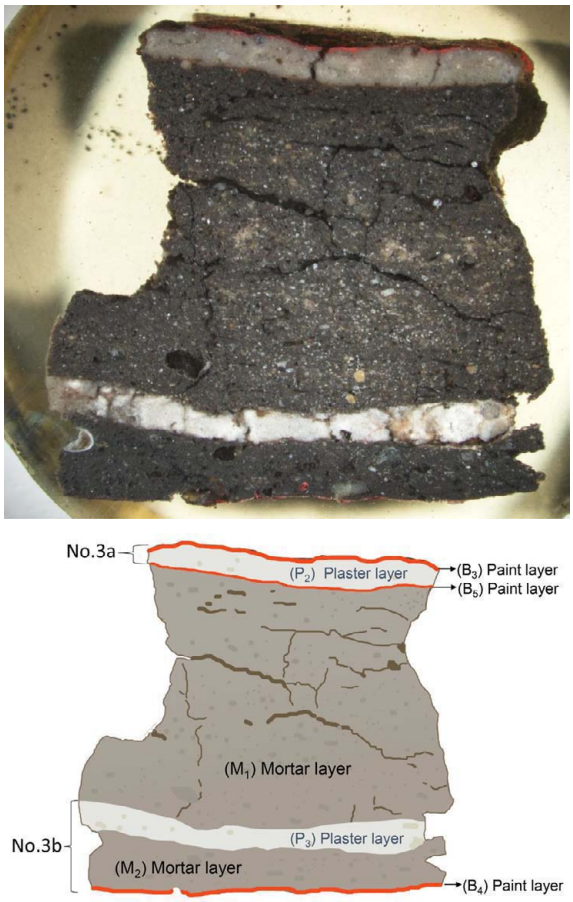


Figure 12. A cross-section image of sample and illustration of its layer structures

XRF, XRD analysis, and SEM/EDX were performed on many of the layers of sample No.3. As a result, a high amount of Si was detected from the plaster layer (P_2, P_3) at points No. 3a_02, 03, and 3b_7 by XRF analysis. The XRD analysis revealed that the plaster layers at point No.3a_11 and No.3b_13 were Orthoclase Al Si_3O_8 (Appendix 3, Table 5).

High Hg content was detected by XRF analysis and SEM/EDX mapping of the red pigment on layer B3 of sample No. 3a (Figure 15) and layer B4 of sample No. 3b. The XRF results are shown in Figures 13 and 14. The red pigment from B3 and B_4 was identified as cinnabar(1(vermilion(2) HgS by XRD analysis. Cinnabar is a well-known pigment in the art and cultural heritage fields. There are three kinds of mercuric sulfide pigments, such as the natural mineral form, which is simply finely ground cinnabar and a synthetic form, which is produced by the dry process, as well as a synthetic form, which is produced by a wet process. The dry-process vermilion was in common use, and was well

(1 The mineralogist and crystallographer have given the common red crystalline form of mercuric sulfide the name cinnabar [Gettens et al. 2012:159-182].

(2 Vermilion is the standard name in England [Gettens et al. 2012: 159-182].

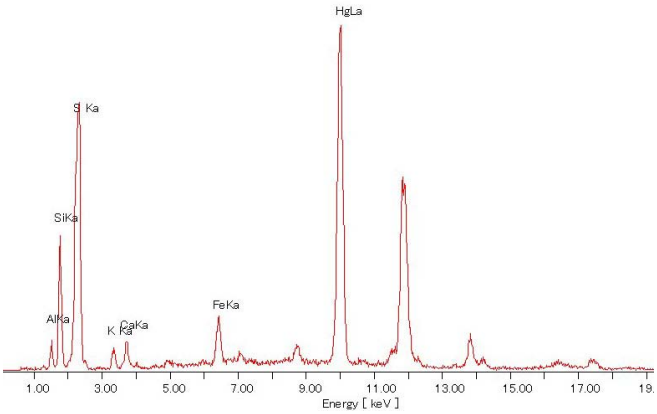


Figure 13. The results of x-ray fluorescence analysis on sample No. 3a.

Measurement point: sample No. 3a_01

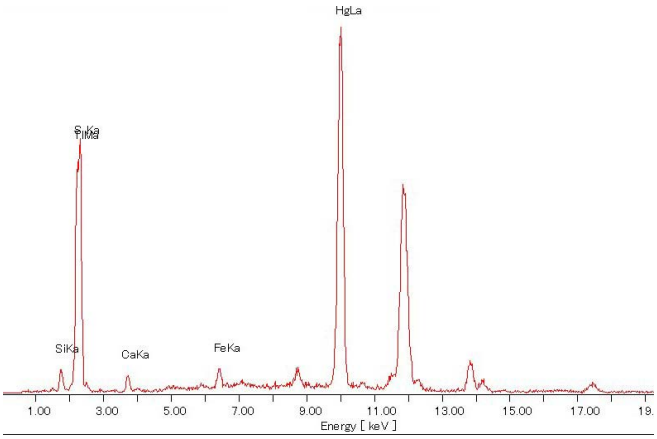


Figure 14. The results of x-ray fluorescence analysis on sample No. 3b.

Measurement point: sample No. 3b_04

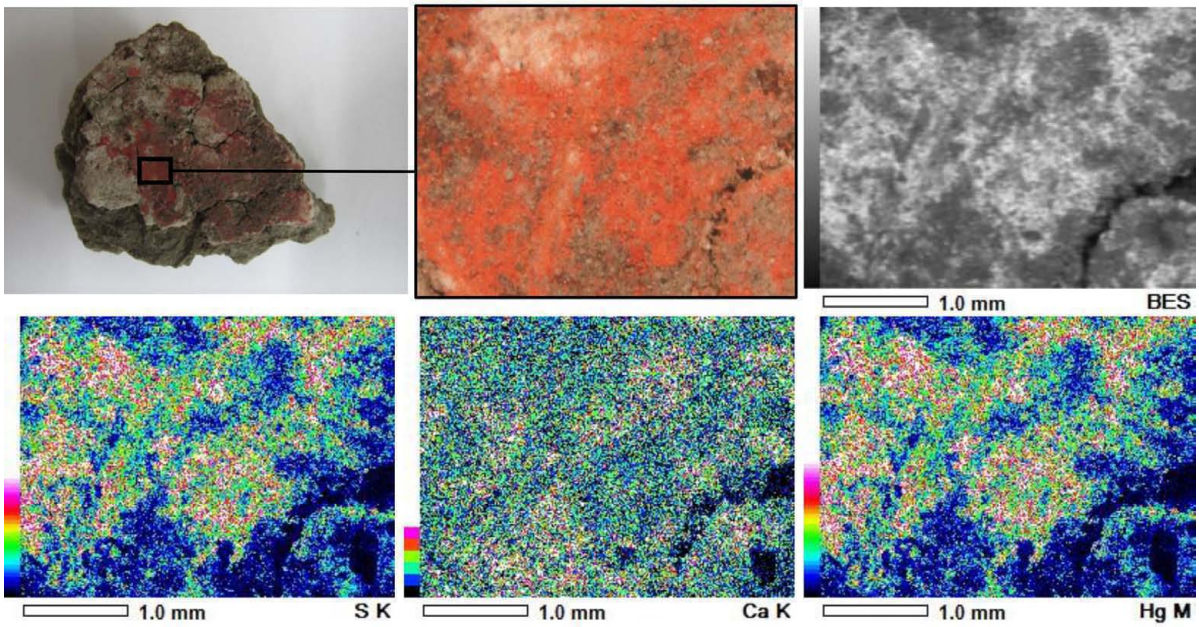


Figure 15. The results of element mapping with SEM/EDX on sample No. 3a, red pigment.

Measurement point: red pigment from layer B_3

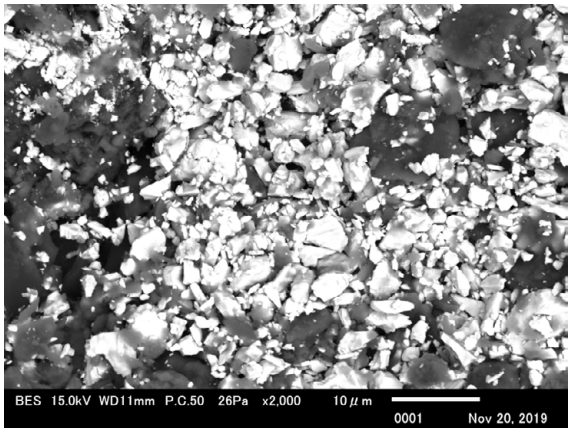


Figure 16. Scaning electron micrographs of red pigment from sample No. 3a, magnification 2000x

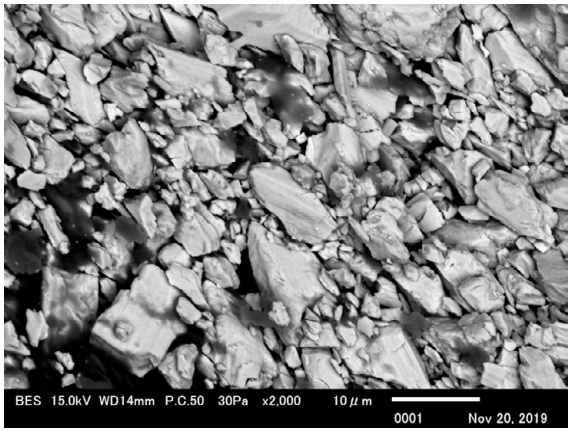


Figure 17. Scanning electron micrographs of red pigment from sample No. 3b, magnification 2000x

developed in China by the 17th century. Gradually, knowledge of the production and manufacture of the pigment may have been transmitted and imported to Western and Asian countries from China [van Vallen 2005].

This type of red paint is used for some murals, including the Kharkhorum ruin [Angaragsuren 2020], Övgön Monastery [Ryu 2020], Tsamba shrine of the Erdene Zuu monastery in Mongolia [Angaragsuren 2018], and Dazhao temple in Inner Mongolia, China [Wei et al. 2010; Du et al. 2002]. It is clear that the particle sizes of the red pigment used in the mural painting of the Ikh Bulagiin Öndör Dovjoo ruin were similar to the particle size of the red pigment in the mural painting of the Kharkhorum ruin and Övgön monastery. In addition, it was estimated that the red pigment wasproduced by a dry method when examining the shape of the pigment particles using SEM.

The particle sizes of red pigment in both section No.3a and 3b were prismatic and approximately 1–10μм in size. SEM examination results were compared between sections 3a and 3b, and pigment particle sizes of section No. 3b were larger than the pigment particle size of section No. 3a. Micrography of the pigment particles is shown in Figures 16 and 17.

Ⅳ. Conclusion

In conclusion, the materials and pigments used in mural paintings excavated from the Ikh Bulagiin Öndör Dovjoo ruin of Sukhbaatar Province, Mongolia, were successfully investigated. Two primary conclusions can be reached:

1) Investigation of the materials and pigments

The green paint in fragments of the mural painting was atacamite ($Cu_7 2Cl_4(OH)10 \cdot H_2O$), the plaster layer was calcite ($CaCO_3$), and the red paint was cinnabar (HgS). The element Pb was detected within the white paint layer at point No. 1_02 and was estimated to be white lead pigment.

2) For further research and excavation

Visual observation of sample No. 1 reveals that it was part of a multi-colored mural. Therefore, when re-excavating this ruin, the original mural pieces should be removed without damage. It may be possible to reassemble the small fragments into a whole.

It is apparent that sample No. 3 has paint layers on both sides with plaster in between. It can be assumed that the surface of the mural painting peeled off and fell forward causing overlap. This should be kept in mind during future excavations.

The results of this investigation can be used to aid future researchers when comparing ancient historical sites and ruins.

It can be observed that the materials used for wall paintings at Sumiin Dovjoo and Ikh Bulagiin Öndör Dovjoo, which are geographically quite close, were very different. This finding can assist other researchers investigating pigment materials and conserving cultural heritage sites.

References

Amartuvshin Ch., Batsaikhan Z., Erdenebat U., Galdan G., Batdalai B., Mandah D., Tselhagarav Ts., Honeychurch W., Wright J., Pleuger S.: Амартүвшин Ч., Батсайхан З., Эрдэнэбат У., Галдан Г., Батдалай Б., Мандах Д., Цэлхагарав Ц., Ханичёрч У., Врайт Ж., Плиугер С., 2018, *Монгол-Американий хамтарсан «Дорнод Монгол: археологийн хайгуул, малтлага судалгаа» төсөл, 2018 оны хээрийн судалгааны ангийн тайлан*, ШУА-ийн АХГБСХ: 19-32. [Institute of History and Archaeology, MAS., *2018 Mongolia and American joint expedition « Dornod Mongol: archaeological survey» excavation study project, report of the survey*]

Angaragsuren O., Kohdzuma Yohsei, 2020, Investigation of the pigments and materials used in some mural paintings of Mongolia, *Journal of Conservation Science, vol.59*, Independent Administrative Institution Tokyo National Research Institute for Cultural Properties: 115–131. [『保存科学』59 号 , (独) 国立文化財機構東京文化財研究所]

Angaragsuren O.: Ангарагсүрэн О, 2008, Эрдэнэ Зуу хийдийн Цамба сүмийн туурган зургийн хадгалалт хамгаалалт, будаг дахь рентген флуоресценцийн спектрометрийн шинжилгээний зарим үр дүнгээс, *Орхоны Хөндийн Өв сэтгүүл, дугаар 5*, УБ: 117-122. [Some results of the handheld X-ray fluorescence spectrometer on pigments and observation of the wall painting at the Tsamba temple of the Erdene Zuu monastery, *Journal of Heritage of Orkhon Valley, No.5*]

杜暁帆・肥塚隆保・沢田正昭・杜暁黎 2002「中国内モンゴル自治区和浩特博物館所蔵大召寺壁画の顔料分析」『考古科学の総合的研究活動報告書』(中核的研究拠点形成プログラム』)III, 奈良国立文化財研究所：238-239. [Du XiaoFan, Takayasu Koezuka, Masaaki Sawada, Du XiaoLi, Pigment analysis of mural paintings of the Dazhao temple stored in the Hohhot museum, Inner Mongolia, China]

FitzHugh E.W., Winter J., Leona M, 2003, Studies using scientific methods, pigments in later Japanese paintings, *Freer Gallery of art occasional papers, vol.1*, Washington. D.C: Smithsonian Institute: 16–17.

Tsogtbaatar B., Lkhündev G., Batdalai B., Amarbold Ye., Osawa T., Otani I.: Цогтбаатар Б., Лхүндэв Г., Батдалай Б., Амарболд Э., Осава Т., Отани И., 2019, Монгол-Японы хамтарсан «Дорнод Монголын эртний түрэгийн үеийн түүх, археологийн судалгаа» төслийн 2019 оны хээрийн шинжилгээний ангийн тайлан, ШУА-ийн АХГБСХ: 6–16. [Institute of Archaeology, MAS. The annual report of Mongol-Japan joint project «History and archeological research during period of Old Turkic of Eastern Mongolia»]

Tsogtbaatar B., Lkhündev G., Batdalai B., Amarbold Ye., Osawa T., Otani I.: Цогтбаатар Ц., Лхүндэв Г., Батдалай Б., Амарболд Э., Осава Т., Отани И, 2019, Их Булагийн Өндөр довжоонд хийсэн малтлагын урьдчилсан үр дүнгээс, *Монголын археологи-2019*, УБ: 77-82. [Preliminary report of the excavation at Ikh Bulgiin Öndör Dovjoo]

Gettens R. J., Feller R. L., Chase W. T, 2012, Chapter 7. Vermilion and Cinnabar, *Artists' pigments: A handbook of their history and characteristics, vol.2*, National Gallery of Art, Washington: 159-182.

Ryu SungWook: 柳 成煜 2020『古代アジアにおける彩色顔料の変遷 ―モンゴル出土顔料の科学的研究―』, 博士学位論文 , 奈良大学大学院文学研究科 . [*Transition of Pigments in Ancient Asia: Scientific research on pigments excavated in Mongolia*, Ph.D. dissertation, Nara University, Graduate School of Letters.]

Wei ShuYa, Schreiner M., Guo Hong, Ma QingLin, 2010, Scientific investigation of the materials in a Chinese Ming dynasty wall painting, *International Journal of Conservation Science, vol.1-2*: Lasi: 99–112.

van Valen L., 2005, *The Matter of Chinese painting, Case studies of 8th century murals, Universiteit Leide*n, Doctoral Thesis.

Abbreviation:

MAS: Mongolian Academy of Sciences

АХГБСХ: Археологийн хүрээлэнгийн гар бичмэлийн сан хөмрөг (Archive document of the Institute of Archaeology)

УБ: Улаанбаатар (Ulaanbaatar)

ШУА: Шинжлэх Ухааны Академи

■ APPENDIX 1:

Results of the optical microscopy of sample No. 1, No. 3a, and No. 3b

Table 1. Results of optical microscopy on sample No. 1

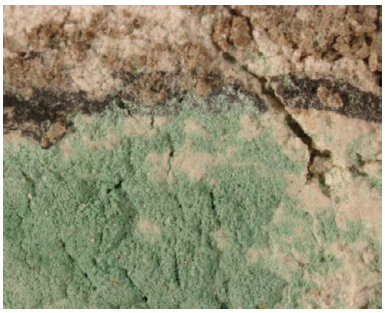
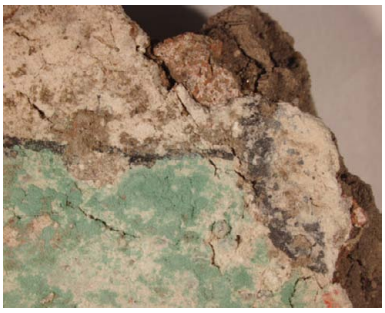
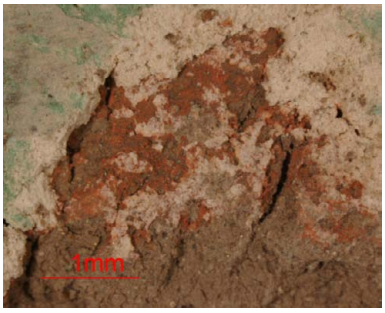
		
A) Magnification, 7x	B) Magnification, 10x	C) Magnification, 100x
		
D) Magnification, 10x	E) Magnification, 10x	F) Magnification, 63x
		
G) Magnification, 10x	H) Magnification, 20x	I)Magnification, 32x

Table 2. Results of optical microscopy on sample No. 3a

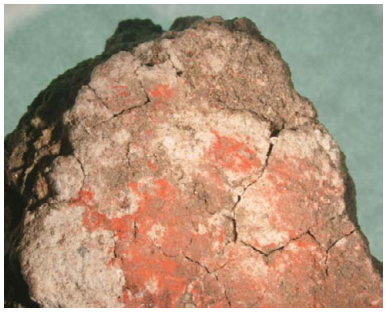
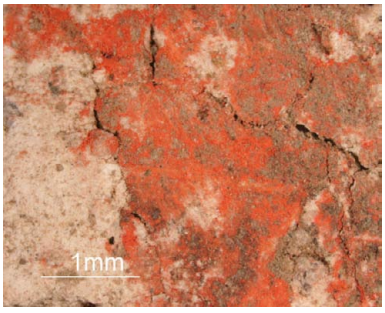
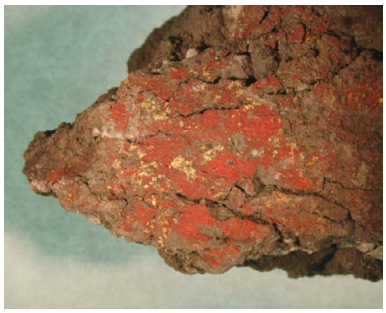
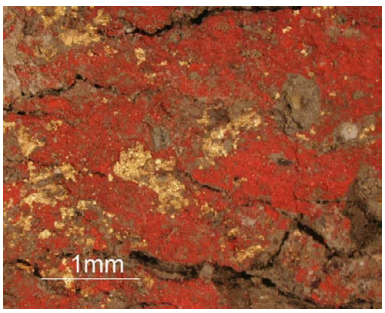
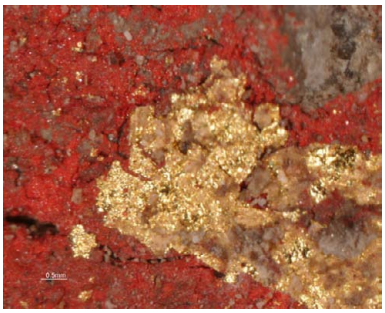
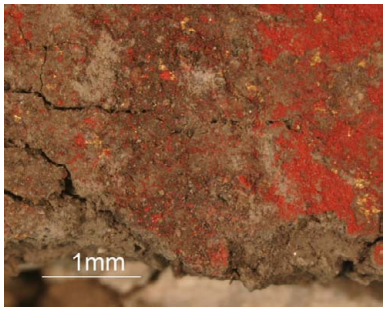
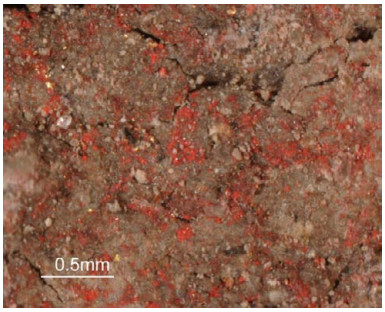
		
A) Magnification, 7x	B) Magnification, 20x	C) Magnification, 100x

Table 3. Results of optical microscopy on sample No. 3b

		
D) Magnification, 7x	E) Magnification, 20x	F) Magnification, 100x
		
G) Magnification, 7x	H) Magnification, 20x	I) Magnification, 80x

■ APPENDIX 2:

XRF and XRD measurement points on samples No. 1, No. 3a, and No. 3b

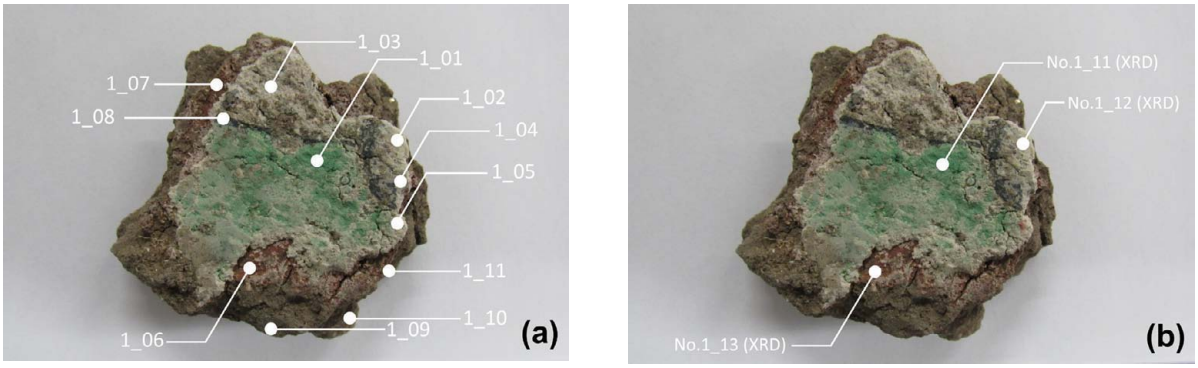


Figure 18. (a) XRF measurement points on sample No. 1; (b) XRD measurement points on the sample No. 1

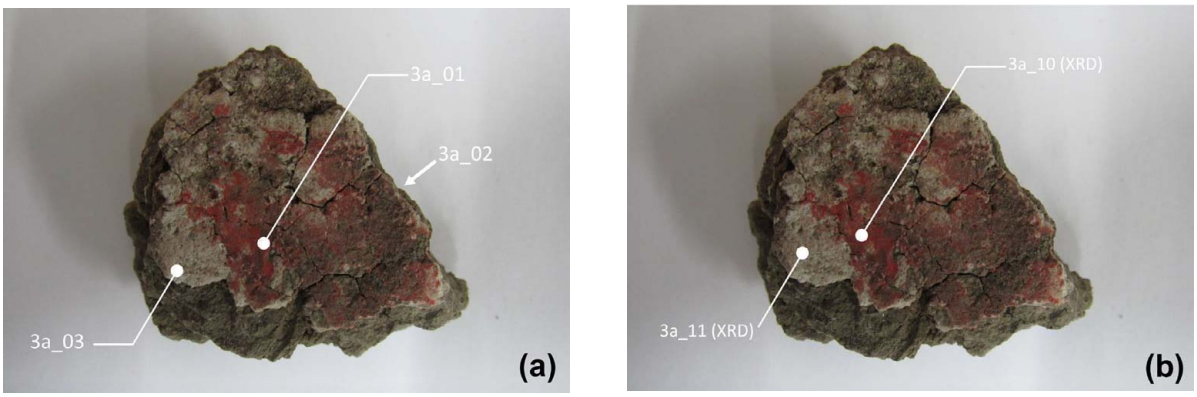


Figure 19. (a) XRF measurement points on sample No. 3a; (b) XRD measurement points on the sample No. 3a

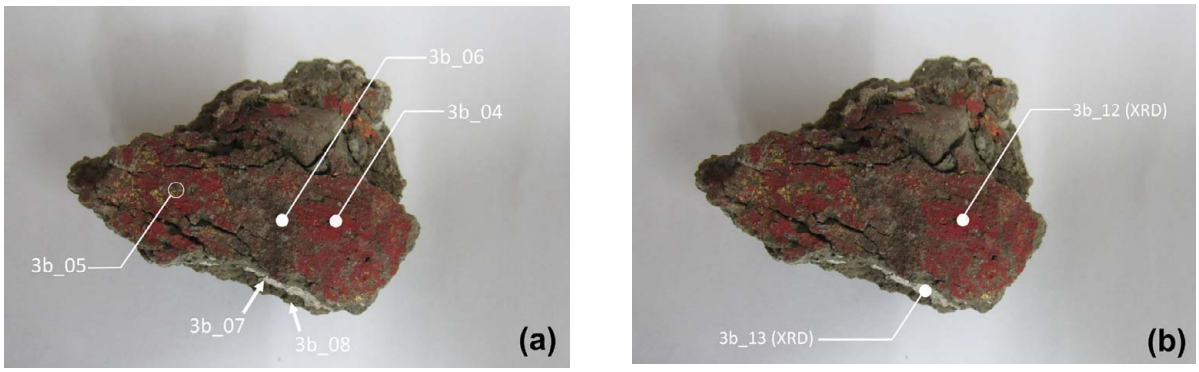


Figure 20. (a) XRF measurement points on sample No. 3b; (b) XRD measurement points on sample No. 3b

■ APPENDIX 3:

Results of XRF and XRD analysis of the Ikh Bulagiin Undur Dovjoo mural painting

Table 4. Results of x-ray fluorescence analysis on sample No. 1, No. 3a, and No. 3b

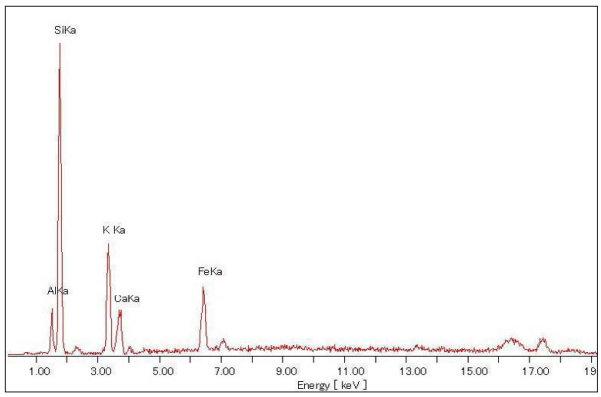
Sample No.	Measurement point	Detected elements
No. 1_01	Green	Cu, CI, S, Fe, Ca
No. 1_02	White	Ca, Pb, As, Si,Fe, Cu
No. 1_03	White	Si, K, Fe, Cu, Al, Ca, Cl, S, Mn
No. 1_04	White	Si, K, Fe, Al, Ca, Ti, Cu, Pb
No. 1_05	Red	Si, S, Hg, K, Fe, Al, Cu
No. 1_06	Red	Ca, Si, Fe, Al, K, Cr, Cu, Ti, S, Mg
No. 1_07	Red	Fe, Ca, Si, K, Al, Ti, Cu
No. 1_08	Black	Si, K, Fe, Cu, Ca, Al, S, Cl, Ti
No. 1_09	Mortar	Ca, Fe, Si, Cu, K, Ti, Al, S, Mn
No. 1_10	Mortar	Ca, Fe, Si, K, Al, Ti
No. 1_11	Mortar	Ca, Fe, Si, Al, K, Ti, Mn
No. 3a_01	Red	Hg, S, Si, Fe, Al, Ca, K
No. 3a_02	White	Si, K, Fe, Ca, Al
No. 3a_03	White	Si, K, Al, Fe, S
No. 3b_04	Red	Hg, S, Ti, Si, Ca, Fe
No. 3b_05	Gold	Hg, Ca, Au, Si, Fe, Cu, Al, K, Ag, Mn
No. 3b_06	Reddish-brown	Hg, Si, S, Fe, Ca, Al, K, Mn, Ti
No. 3b_07	White	Si, K, Fe, Ca, Al
No. 3b_08	Mortar	Ca, Fe, Si, K, Al

Table 5. Results of XRD analysis on sample No. 1, No. 3a, and No. 3b

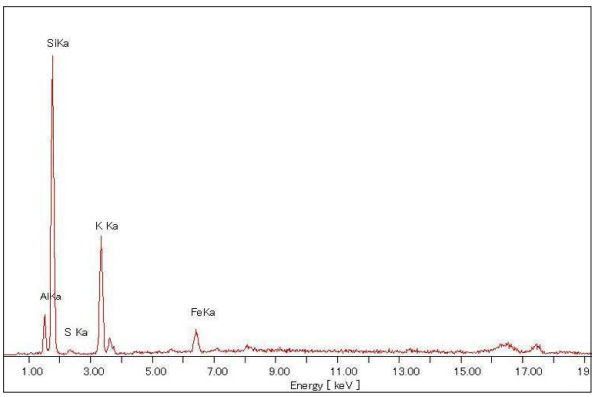
Sample No.	Measurement point	Detected elements
No. 1_11 (XRD)	Green	Atacamite $Cu_7 2Cl_4(OH)10 \cdot H_2O$, quartz SiO_2
No. 1_12 (XRD)	White	Aragonite $Ca(CO_3)$, Calcite $CaCO_3$, quartz SiO_2
No. 1_13 (XRD)	Red	Quartz SiO_2, Hematite ? $Fe2O_3$
No. 3a_10 (XRD)	Red	Cinnabar HgS, quartz SiO_2
No. 3a_11 (XRD)	White	Orthoclase K Al Si_3O_8, quartz SiO_2
No. 3b_12 (XRD)	Red	Cinnabar HgS
No. 3b_13 (XRD)	Plaster layer	Orthoclase K Al Si_3O_8, quartz SiO_2

■ APPENDIX 5:

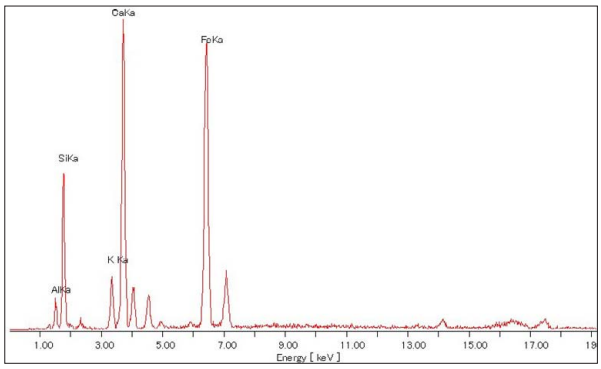
Results of x-ray fluorescence analysis on sample No. 3a and No. 3 (Graphic data)



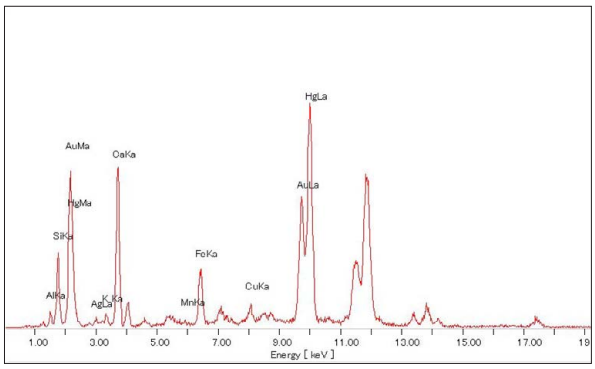
No. 3a_02 (White)



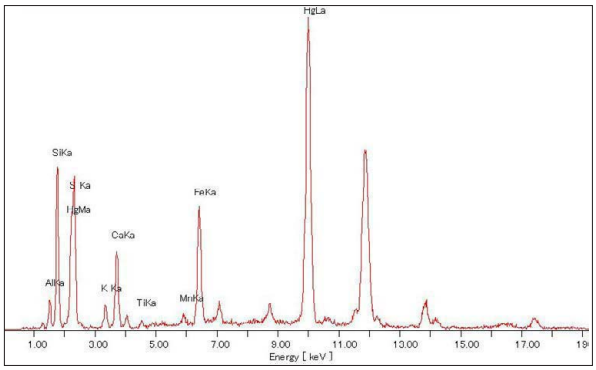
No. 3a_03 (White)



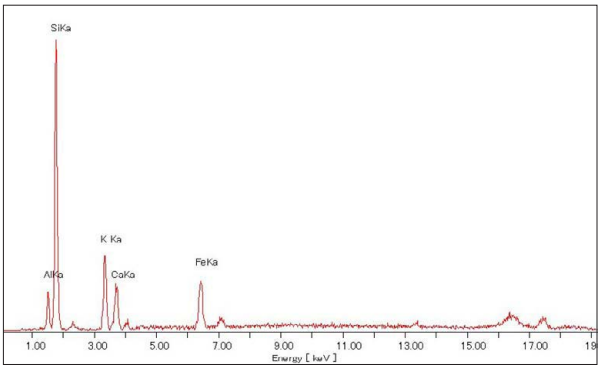
No. 3b_05 (Gold)



No. 3b_06 (Reddish-brown)



No. 3b_07 (White)



No.3b_04 (Mortar)

Abstract:

Монгол улсын Сүхбаатар аймгийн Түвшинширээ сумын Их Булагийн тууриас илэрсэн ханын зургийн материалын шинжилгээ

Одхүүгийн Ангарагсүрэн

(Киото их сургуулийн
хүн ба байгаль шинжлэлийн сургууль)

Коүзүма Ёүсэй

(Нарагийн соёлын өвийн үндэсний судалгааны
хүрээлэн)

Монгол улсын ШУА Түүх, Археологийн Хүрээлэн, Япон улсын Осака Их Сургуулийн хамтарсан “Дорнод Монголын эртний түрэгийн үеийн түүх, археологийн судалгаа” төслийн хүрээнд Сүхбаатар аймгийн Түвшинширээ сумын нутаг дахь Их Булаг голын Өндөр Довжоо хэмээх дурсгалыг малтан судалжээ. Малтлагаас илэрсэн ханын зургийн дээжид будаг, материалын шинжилгээг хийж гүйцэтгэв. Шинжилгээнд оптик микроскоп, рентген флуоресценц спектр (XRF), рентген дифрактометр (XRD), скан электрон микроскоп

(SEM/EDX) багажийг туе туе ашиглалаа. Судалгааны үр дүнд No.1 дээжийн ногоон хэсгээс атакамайт ($Cu_7Cl_4(OH)10{\cdot}H_2O$), No.3 дээжийн улаан хэсгээс мөнгөн усны хүдрийн будаг (HgS) туе туе илэрч, суурь давхарга нь кальцит ($CaCO_3$) болох нь тогтоогдов.

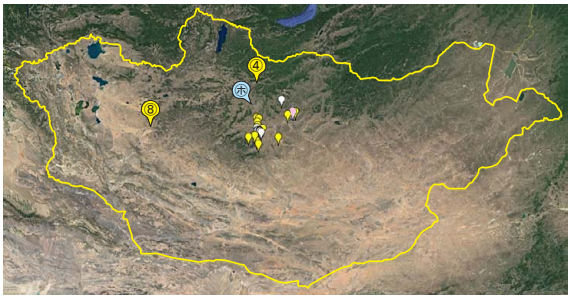
モンゴル国スフバータル県（アイマク）トゥブシンシレー郡（ソム）に所在するイフ・ボラギーン・ウンドゥル・ドブジョー遺跡で発見された壁画材料の分析

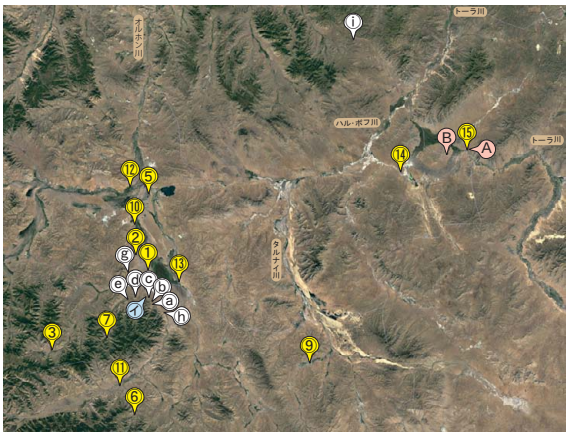
オドフー　アンガラグスレン
（京都大学、大学院人間・環境学研究科）

髙妻洋成
奈良文化財研究所

モンゴル科学アカデミー歴史学・考古学研究所と大阪大学は「東部モンゴルの突厥期の歴史・考古学研究」プロジェクトに基づき、スフバータル県（アイマク）トゥブシンシレー郡（ソム）にあるイフ・ボラク川（ゴル）の石築基檀遺跡（ドブジョー (Dovjoo)）を発掘した。本研究は発掘中に発見された壁画サンプルに対して顔料と材料の分析を行ったものである。分析は光学顕微鏡、蛍光X線分析 (XRF)、X線回折分析 (XRD)、走査型電子顕微鏡観察 (SEM) の手法を用いて壁画材料の同定を行なった。分析の結果、サンプル No.1 の緑色部分からはアタカマイト ($Cu_7Cl_4(OH)10{\cdot}H_2O$) が、サンプル No.3 の赤色部分からは水銀朱（HgS）、漆喰層からはカルサイト ($CaCO_3$) が検出された。

（67 頁よりつづく）





5. 言及されている遺跡

A: ザーマル古墳（僕固乙突墓）　B: オラーン・ヘレム壁画墓　（①～⑮, ⓐ～ⓘ, ㋑, ㋥は目次記載遺跡に対応。㋺はⓑ、㋩はⓓ、㋭はⓔ付近か範囲内。ⓕは不明）

参考文献：

Chuluun S., Tsebeendorj D. [ed]: Чулуун С., Цэвээндорж Д. [ред], 2017, *Эртний нүүдэлчдийн урлагийн дурсгал (Монголын археологийн өв, боть VII)*, УБ. [Cultural Monuments of ancient nomads (Archaeological relics of Mongolia, vol.VII)]

Ochir A., Odbaatar Ts., Erdenebold L., Ankhbayar B.: Очир А., Одбаатар Ц., Эрдэнэболд Л., Анхбаяр Б., 2019, *Монгол улсын нутаг дахь уйгурчуудын археологийн дурсгал*, УБ.

なお、図 1,2 報告書の書誌情報は村上論文参照。（大谷）